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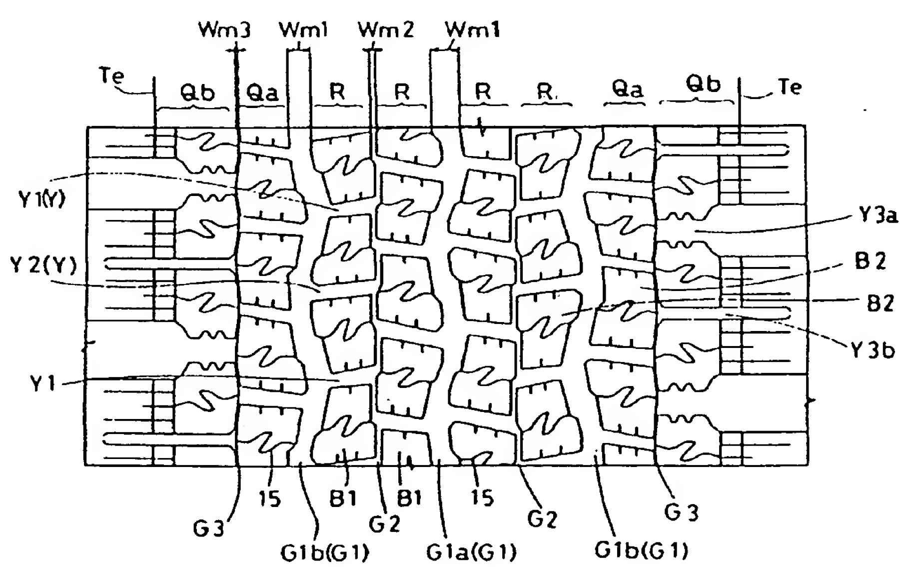
(54) Heavy duty pneumatic tyre

(57) A heavy duty pneumatic tyre comprises a tread portion (5) which is provided with wide circumferential grooves (G1) having a width Wml of 4.0 mm to 20.0 mm and narrow circumferential grooves (G2) having a width Wm2 of not less than 2.0 mm but less than 4.0 mm, and each region (R) which is defined between one of the wide circumferential grooves (G1) and the axially adjacent narrow circumferential groove (G2) is provided with axial grooves (Y) extending from the wide circumferential groove to the narrow circumferential groove to circumferentially divide the region into blocks (B1), wherein the axial grooves (Y) include variable-width grooves (Y1) the width of which increases from the wide circumferential groove (G1) to the narrow circumferential groove (G2).

Fig. 2



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Description

The present invention relates to a pneumatic tyre for heavy duty vehicles and more particularly to an improvement in the tread portion capable of improving the resistance to abnormal tread wear.

In winter tyres, snow tyres, studless tyres and the like which are used on snowy and icy roads, usually, the necessary road grip on the snow is mainly obtained by the use of tread blocks defined by relatively wide tread grooves, and that on the ice is mainly obtained by the use of a relatively soft tread rubber compound and edges of the tread rubber formed by the wide tread grooves, narrow grooves and sipes. Accordingly, the blocks are inevitably decreased in rigidity, and uneven wear is liable to occur. As a result, it is difficult to maintain the required snow performance throughout the tread wear life. This is especially remarkable in pneumatic tyres for heavy duty vehicles such as trucks, buses and the like.

The inventors made a study of uneven wear of such tread blocks and found that uneven wear is liable to occur in blocks divided by a wide circumferential groove and narrow circumferential groove and the wear progresses faster on the wide circumferential groove side of the blocks than the narrow circumferential groove side.

It is therefore, an object of the present invention to provide a heavy duty pneumatic tyre in which blocks divided by wide circumferential grooves and narrow circumferential grooves are prevented from abnormal wear and the snow performance can be maintained throughout the tread wear life.

According to the present invention, a heavy duty pneumatic tyre is provided in the tread portion with wide circumferential grooves having a width Wm1 of 4.0 mm to 20.0 mm, narrow circumferential grooves having a width Wm2 of not less than 2.0 mm but less than 4.0 mm, and axial grooves each extending from one of the wide circumferential grooves to the adjacent narrow circumferential groove to form blocks, the axial grooves having a variable-width increasing from the wide circumferential groove to the narrow circumferential groove.

Therefore, the blocks are increased in rigidity on the wide groove side compared to the narrow groove side, and as a result, the movements of the blocks are evened to decrease abnormal wear.

Embodiments of the present invention will now be described in detail in conjunction with the accompanying drawings, in which:

Fig.1 is a cross sectional view of an embodiment of the present invention;
Fig.2 is a developed plan view showing an example of the tread pattern;
Fig.3 is an enlarged partial plan view showing an example of the variable width axial groove and constant width axial groove;
Fig.4 is a schematic view showing a typical shape of sipe;
Fig.5 is a developed plan view showing another example of the tread pattern; and
Figs.6, 7 and 8 are developed plan views showing the tread patterns of the reference tyres in Table 1.

In Fig.1, a heavy duty pneumatic tyre 1 of the present invention is a winter tyre of size 11R22.5.

The tyre comprises a tread portion 5, a pair of axially spaced bead portions 3 each with a bead core 5 therein, a pair of sidewall portions 4 extending between tread edges Te and the bead portions 3, a carcass 6 extending between the bead portions, and a belt 7 disposed radially outside the carcass 6 and inside a rubber tread.

In the tyre meridian section, the tread face 5S (i.e. the outer surface of the tread portion 5) is defined by a convex curved line, for example, a single radius arc having a centre on the tyre equatorial plane.

The carcass 6 is composed of at least one ply of cords arranged radially at an angle of 70 to 90 degrees with respect to the tyre equator C and extending between the bead portions 3 through the sidewall portions 4 and under tread portion 5 and turned up around the bead cores 2 from the inside to the outside of the tyre to be secured thereto. For the carcass cords, organic fibre cords, e.g. nylon, polyester, rayon, aromatic polyamide fibre and the like, and inorganic fibre cords, e.g. steel cords can be used. The carcass 6 in this example is composed of a single ply 6A of steel cords arranged at an angle of substantially 90 degrees.

The belt 7 comprises at least two crossed breaker plies. In this example, the belt 7 comprises four breaker plies each made of steel cords laid parallel with each other. In the radially innermost first ply 7A, the cord angles are in the range of from 50 to 70 degrees, and in the second to fourth plies 7B, 7C and 7D the cord angles are not more than 30 degrees with respect to the tyre equator C.

In the tread face 5S, circumferential grooves G extending continuously in the circumferential direction and axial grooves Y are disposed to form blocks.

The circumferential grooves G comprise wide circumferential grooves G1 having an axial width Wml of 4.0 mm to 20.0 mm, and narrow circumferential grooves G2 having an axial width Wm2 of not less than 2.0 mm but less than 4.0 mm.

It is preferable for improving the water drainage to dispose the wide circumferential grooves G1 in a central tread region Tc where the ground pressure is high, which region Tc is defined as having a width of 0.6 times the tread width TW.

If all the circumferential grooves G are formed as wide circumferential grooves G1, the total area of the grooved part of the tread is excessively increased, and the wet and dry running performance and wear resistance, especially uneven wear resistance greatly decrease. On the contrary, if all the circumferential grooves G are formed as narrow circumferential grooves G2, the required drainage and on-the-snow performance can not be obtained. Thus, the provision of both wide circumferential grooves G1 and narrow circumferential grooves G2 is essential, and it is especially pref rable to dispose them alternately in the axial direction.

In the example shown in Fig.2, three wide circumferential grooves G1 and two narrow circumferential grooves G2 are disposed alternately in the axial direction, and in addition thereto, two fine grooves G3 having an axial width Wm3 of less than 2.0 mm are further disposed in the tread face 5S. The three wide grooves G1 are a groove G1a extending on the tyre equator C and a groove G1b disposed on each side of the tyre equator C. The fine grooves G3 are disposed between the axially outer wide grooves G1b and the adjacent tread edges Te. The grooves G1 have a depth Hg1 and are deeper than any other groove of the circumferential grooves G and axial grooves Y. The wide grooves G1 in this example are zigzag grooves, and the width of the grooves is periodically varied in the circumferential direction according to the zigzag pitches. For example, the groove depth Hg1 is 18 to 21 mm, the minimum width is 7 mm, and the maximum width is 13 mm.

The narrow grooves G2 and fine grooves G3 in this example are zigzag grooves each having a substantially constant groove width. However, it is also possible to vary the groove width of these grooves within the range between the minimum width and maximum width in the same manner as the wide circumferential grooves G1. The groove depths of the narrow grooves G2 and fine groove G3 are not more than the groove depth Hg1 of the wide grooves G1, and in this example, these are set in the range of from 10 to 13 mm.

The regions R between the adjacent wide and narrow grooves G1 and G2 are each provided with axial grooves Y extending across the full width of the region R to divide the region into a circumferential row of blocks B1.

The axial grooves disposed in each region Ra, Rb include variable-width grooves Y1 whose width Wy increases from the open end 10 on the wide groove Gla side to the open end 11 on the narrow groove G2a side. The region Ra is between the wide groove G1a and the narrow groove G2, and the region Rb is between the narrow groove G2 and the wide groove Glb.

The axial grooves in this example further include constant-width axial grooves Y2 whose width Wy is constant. Here, the widths Wy of the axial grooves are defied as the width measured in the circumferential direction of the tyre. The variable-width grooves Y1 and the constant-width grooves Y2 are disposed alternately in the axial direction. The constant-width axial grooves Y2 are arranged in substantially parallel with the variable-width grooves Y1. In this example, the axial grooves Y are straight grooves extending at small angles α to the tyre axial direction. The angle α is defined at the groove centre line, and is set in the range of not more than 30 degrees, preferably not more than 20 degrees, more preferably not more than 15 degrees for grip performance. Also it is possible to form the axial grooves Y as a curved groove, a bent or zigzag groove, or the like. In this case, the above-mentioned angle α is defined as of the straight line drawn from the groove centre at one of the open ends 10 and 11 to that at the other.

The width Wy of the variable-width grooves Y1 increases continuously from the open end 10 to the open end 11 at a substantially constant rate. However, it is also possible to change the width Wy at a variable rate or step-by-step.

The difference (Wy1-Wy0) of the width Wy1 at the open ends 11 from the width Wy0 at the open ends 10 is about 0.5 to 2.5 mm or 0.02 to 0.2 times the length Ky of the variable-width groove Y1.

The average (Wy1+Wy0)/2 of the variable width Wy is not less than 4.0 mm, preferably not less than 5.0 mm.

On the other hand, the width Wy of the constant-width axial grooves Y2 is set in the range of from 0.7 to 1.5 times the average width (Wy1+Wy0)/2.

As a result, the circumferential length of the blocks B1 is increased on the wide circumferential groove G1 side more than the narrow circumferential groove G2 side, and the blocks B are optimised in respect of rigidity in the circumferential direction, and uneven wear is thus minimised.

It is also possible to form all the axial grooves as variable-width grooves Y1, but the alternate variable-width and constant-width groove arrangement is somewhat preferable because a variable-width groove is a little inferior to a constant-width groove in respect of drainage and resistance to being blocked by packed snow. In addition to the above-mentioned regular alternate arrangement, the variable-width grooves Y1 and the constant-width grooves Y2 may be arranged irregularly. In any case, such arrangements are most effectual in the above-mentioned central tread region Tc where the ground pressure is high.

The blocks B1 in the regions Ra and Rb are each provided with sipes 15 extending axially between the circumferential grooves G1 and G2 in order to obtain the required on-the-ice performance. The sipes 15 are a cut or slit having a width of 0.4 to 1.0 mm, and the depth of the sipes 15 is 0.4 to 0.7 times the depth Hgl of the wide circumferential grooves G1 and not more than the depth of the narrow circumferential grooves G2. The number of the sipes 15 is one per a block. The total length L1 of a sipe 15 therealong is set in the range of from 1.0 to 3.0 times the straight length L2 between the ends 19 and 20 thereof. If the number of the sipes 15 is two or more per block and/or L1/L2 is more than 3.0, even the minimal block rigidity required for the heavy duty tyres can not be obtained, and blocks are liable

to be torn off.

The sipe 15 in this example has a substantially Z-shaped configuration formed by a first segment 15a extending from one end 19, a second segment 15b extending from th other end 20, and a third segment 15c extending therebetween as shown in Fig.4 as a typical model. The straight line VL drawn between the ends 19 and 20 is substantially parallel to the axial grooves Y such that the angle difference therebetween is limited to within plus/minus five degrees.

The sum (J1+J2) of the lengths J1 and J2 of the components of the segments 15a and 15b in the direction parallel to the straight line VL is more than the length of the straight length L2. Accordingly, the segments 15a and 15b are overlapped in the circumferential direction.

The length V of the overlap 16 of the segments 15a and 15b is preferably set to meet

$$V/J1=0.1 \text{ to } 0.9,$$

and

$$V/J2=0.1 \text{ to } 0.9.$$

If V/J1 or V/J2 is less than 0.1, the sipe is liable to crack in the bottom. If more than 0.9, the intersecting angles $\beta 1$ and $\beta 2$ between the segments 15a, 15b and 15c become too small, and the sipe is liable to crack at the intersecting points. Therefore, the angles $\beta 1$ and $\beta 2$ are not less than 16 degrees, preferably not less than 24 degrees but not more than 70 degrees. The angle θ of the central third segment 15c is in the range of from 30 to 83 degrees with respect to the straight line VL.

By this generally Z-shape configuration, the length of edge is increased to improve on-the-ice performance. Further, as the pieces Bf and Br of a block divided by the sipe 15 engage each other, movements thereof are controlled, that is, the block is increased in apparent rigidity. Therefore, not only are the blocks prevented from being damaged but also the steering stability is improved. Further, on-the-ice performance and the resistance of block to uneven wear is improved.

In this example, the region Qa between the outer wide circumferential groove G1b and the fine circumferential groove G3, and the region Qb between the fine circumferential groove G3 and the tread edge Te, are provided with axial grooves to divide each region Qa, Qb into a circumferential row of blocks B2. The blocks B2 are each provided with one sipe 15.

Similarly to the above-mentioned axial grooves in the regions Ra and Rb, the axial grooves in the region Qa include alternately arranged constant-width axial grooves Y2 and variable-width grooves Y1 whose width Wy increases from the open end 10 on the wide circumferential groove G1 side to the open ends 12 on the fine circumferential groove G3 side.

In the axially outer region Qb, wide axial grooves Y3a and narrow axial grooves Y3b are alternately disposed to improve the grip performance and to control a temperature rise in the vicinity of tread edge during running.

Fig.5 shows another example of the tread portion, which is provided with two wide circumferential grooves G1 disposed in the central tread region Tc, three narrow circumferential grooves G2 disposed between the two wide circumferential grooves G1, and two narrow circumferential grooves G2 each disposed between one of the wide circumferential grooves G1 and the adjacent tread edge Te. All the circumferential grooves G1 and G2 are straight and the widths are constant along the longitudinal direction. However, it is also possible to use a straight groove, zigzag groove and wavy groove alone or in combination.

Each of the four regions R between the adjacent wide circumferential grooves G1 and narrow circumferential grooves G2 is provided with variable-width grooves Y1 and constant-width axial grooves Y2 which are alternately disposed in the circumferential direction.

The regions P between the adjacent narrow circumferential grooves G2 are provided with constant-width axial grooves Y2. However, it is also possible that variable-width grooves Y1 and constant-width axial grooves Y2 are alternately disposed in the circumferential direction.

All the blocks B in the tread portion are each provided with a straight sipe 15 substantially parallel with the axial grooves Y1 and Y2. However, it is also possible to use Z-shaped sipes and the like.

Comparison Tests

Test tyres were made and tested for snow performance, uneven wear resistance and wear resistance.

The test tyres all were the same internal structure shown in Fig.1 except for the tread pattern. The specifications of the tread pattern are given in Table 1.

Carcass:	one ply of steel cords (3+7) arranged radially at 90 deg.
Belt:	four plies of steel cords (3+6)
Belt cord angle (deg.):	50/18/18/18 (radially inside to outside)
Belt cord inclination:	Right/Right/Left/Left
Tread width TW:	230 mm
Tyre size:	11R22.5
Rim size:	7.50X22.5
Inner pressure:	8.0kgf/sq.cm
Test car:	10 ton truck (wheel type: 2/2-D)

* Snow performance test

A braking test and a starting test were conducted.

In the braking test, the distance to stop when a full wheel lock braking was applied to the test car running on a snowy test road at a speed of 30 km/h was measured. The results are indicated in table 1, using an index based on Ref. 1 being 100, where the larger the index, the shorter the braking distance.

In the starting test, starting and accelerating the test car on the snowy road, the traction was evaluated by the driver's feeling. The results are also indicated in table 1, using an index based on Ref.A1 and Ref.B1 being 100, where the larger the index, the larger the traction.

* Uneven wear resistance test

The test car was run on dry asphalt-surfaced roads for 5,000 km, and then the wear difference of each block between a wide-groove-side part and a narrow-groove-side part was measured.

* Wear resistance test

The test car was run on dry asphalt-surfaced roads for 30,000 km, making a tyre rotation. Then, the wear of each block was measured to obtain the mean value. The ratio of the running distance to the mean value was calculated as the wear resistance. Thus the larger the value, the better the wear resistance.

* Total performance test

Based on the above-mentioned snow performance, uneven wear resistance and wear resistance, the total performance of the tyres was evaluated for a winter tyre. The results are indicated by an index based on Ref.A1 and Ref. B1 being 100. The larger the value, the better the overall performance.

TABLE 1

Tyre	Ref.A1	Ref.A2	Ex.A1	Ref.B1	Ex.B1
Tread pattern	Fig.6	Fig.7	Fig.5	Fig.8	Fig.2
Wide circumferential groove					
Width Wm1 (mm)	11(average)				
Depth Hg1 (mm)	20.6				
Narrow circumferential groove					
Width Wm2 (mm)	2.5				
Depth (mm)	12				
Variable-width axial groove					
Width (Wy1+Wy0)/2 (mm)	---	5 to 6			
Wy1-Wy0 (mm)	---	0.5 to 2.0			
Constant-width axial groove					
Width (mm)	5	5			

TABLE 1 (continued)

Tyre	Ref.A1	Ref.A2	Ex.A1	Ref.B1	Ex.B1
Tread pattern	Fig.6	Fig.7	Fig.5	Fig.8	Fig.2
Snow performance					
Braking	100	103	100	100	100
Starting	100	103	98	100	102
Uneven wear resistance (mm)	2.2	2.6	2	2	1.6
Wear resistance (km/mm)	12000	11000	14000	16000	17000
Total performance	100	100	102	100	102

As apparent from Table 1, Ex.A1 was slightly inferior to Ref.A1 having constant-width axial grooves only when new in respect of on-the-snow starting performance, but superior in respect of uneven wear resistance and wear resistance. Accordingly, the fully snow performance was displayed stably from the initial stage to the final stage of the tread wear life.

As to Ref.A2 which was provided with variable-width grooves Y1' whose groove width decreased from the wide circumferential groove to the narrow circumferential groove instead of the variable-width grooves Y1, the blocks were more worn on the wide circumferential groove side than the narrow circumferential groove side. As a result, the uneven wear resistance and wear resistance were further decreased. Ref. A2 was superior to Ex.A1 in the snow performance when new, but the snow performance was quickly decreased as the tyre was used. And there is the possibility that the blocks are torn off.

Ex.B1 was improved in the snow performance, uneven wear resistance and wear resistance in comparison with Ref. B1.

Claims

1. A heavy duty pneumatic tyre comprising a tread portion (5), provided with wide circumferential grooves (G1) having a width Wml of 4.0 mm to 20.0 mm and narrow circumferential grooves (G2) having a width Wm2 of not less than 2.0 mm but less than 4.0 mm, regions (R) each defined between one of the wide circumferential grooves (G1) and the axially adjacent narrow circumferential groove (G2), each said region (r) being provided with axial grooves (Y) extending from the wide circumferential groove to the narrow circumferential groove to circumferentially divide the region into blocks (B1), characterised in that the axial grooves (Y) in each said region (R) including variable-width grooves (Y1) the groove width of which increases from the wide circumferential groove (G1) to the narrow circumferential groove (G2).

2. A heavy duty pneumatic tyre according to claim 1, characterised in that said axial grooves (Y)in each of the regions (R) include constant-width grooves (Y2) the groove width of which is constant.

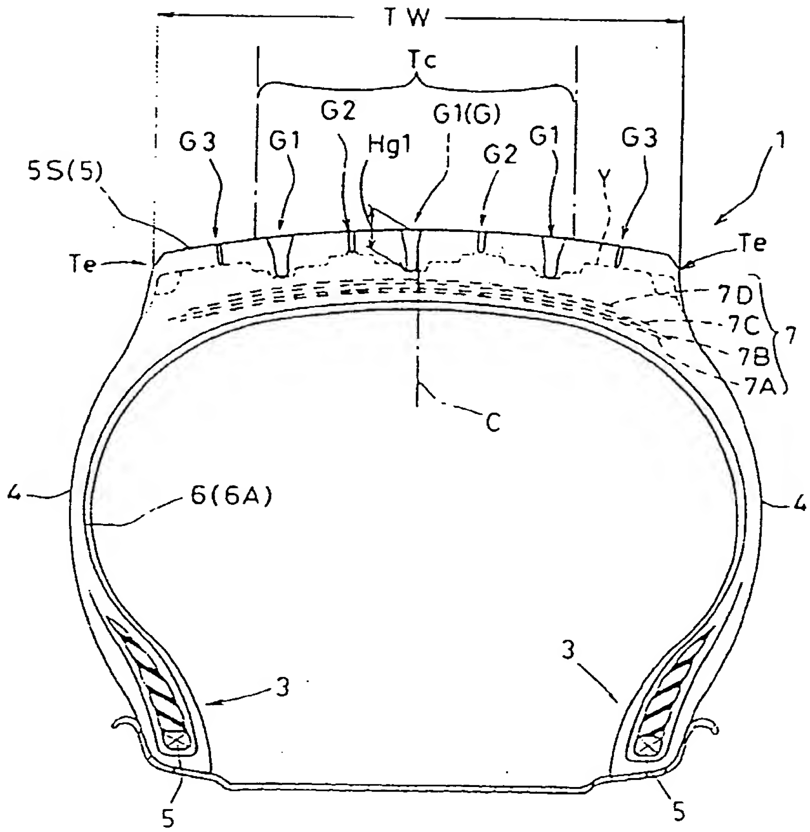
3. A heavy duty pneumatic tyre according to claim 2, characterised in that the variable-width grooves (Y1) and the constant-width grooves (Y2) are disposed alternately in the tyre circumferential direction.

4. A heavy duty pneumatic tyre according to any of claims 1 to 3, characterised in that said blocks (B1) are provided with sipes (15) extending from the wide circumferential groove (G1) to the narrow circumferential groove (G2).

5. A heavy duty pneumatic tyre according to claim 4, characterised in that each said block (B1) is provided with a sipe (15) extending from the wide circumferential groove (G1) to the narrow circumferential groove (G2), and the length of the sipe (15) is in the range of from 1.0 to 3.0 times the distance between the ends (19,20) of the sipe.

6. A heavy duty pneumatic tyre according to any of claims 1 to 5, characterised in that the wide circumferential grooves (G1) and the narrow circumferential grooves (G2) are disposed alternately in the tyre axial direction, and said circumferential grooves (G1,G2) include at least two narrow grooves and at least three wide grooves.

Fig. 1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Tc
G3
G1
G2
Hg1
G1(G)
G2
G1
G3
1
5S(5)
Y
Te
Te
7D
7C
7B
7A
7
C
4
6(6A)
4
3
3
5
5

Fig. 2

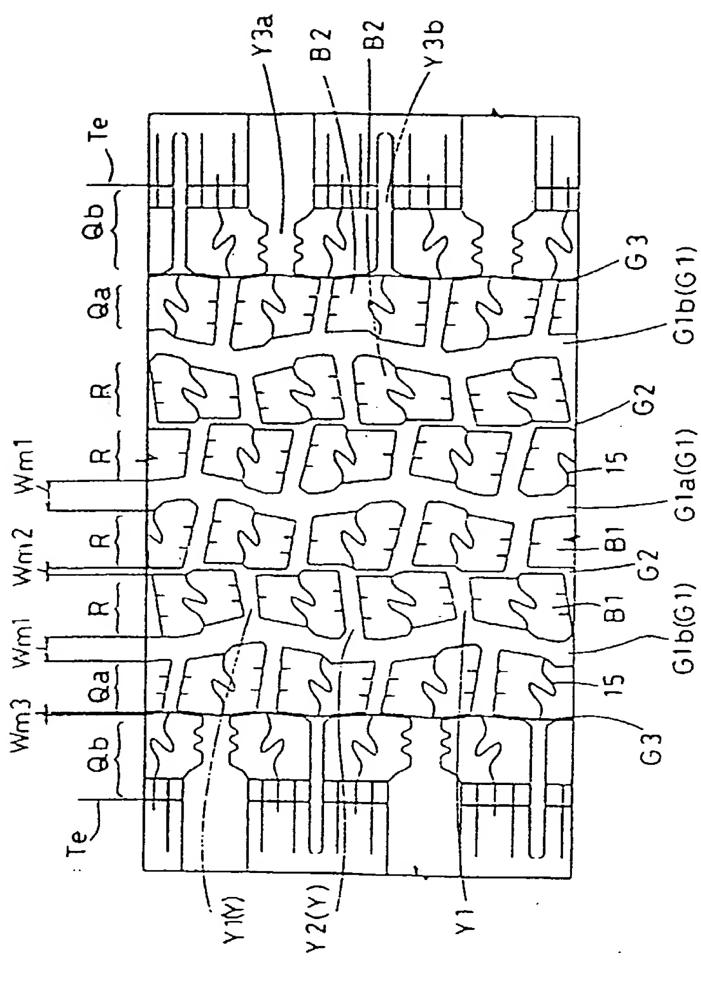
Te
Qb
Qa
R
R
Wm1
R
Wm2
R
Wm1
Qa
Wm3
Qb
Te
Y1(Y)
Y2(Y)
Y1
Y3a
B2
B2
Y3b
G3
G1b(G1)
G2
15
G1a(G1)
B1
G2
B1
G1b(G1)
15
G3

Fig. 3

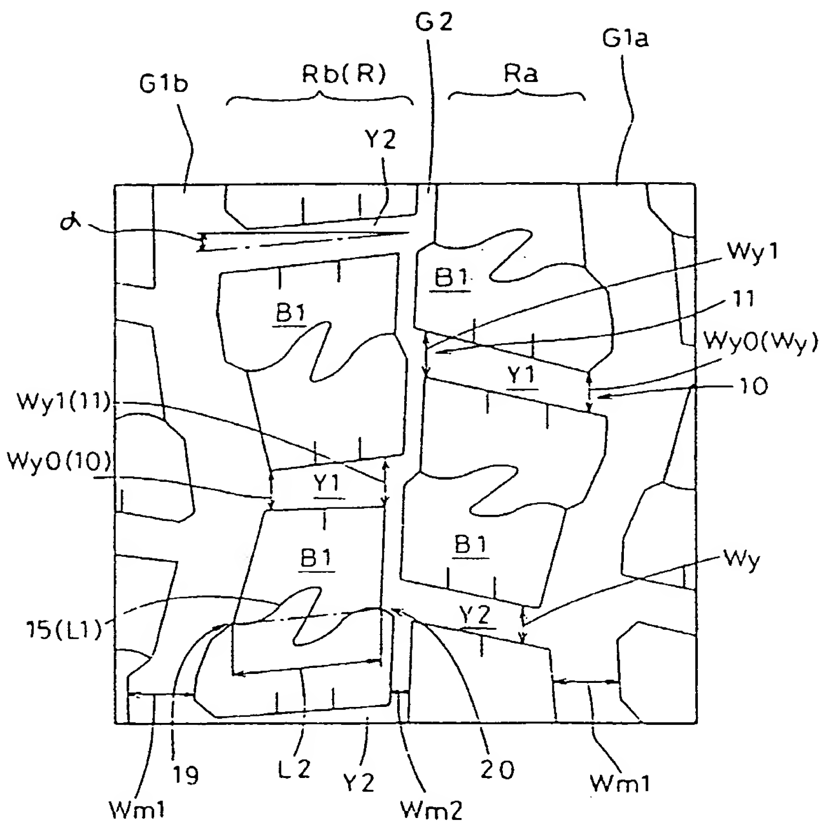
G2
G1a
G1b
Rb(R)
Ra
Y2
α
Wy1
B1
B1
11
Wy0(Wy)
Y1
10
Wy1(11)
Wy0(10)
Y1
B1
B1
Wy
15(L1)
Y2
19
L2
Y2
20
Wm1
Wm1
Wm2

Fig. 4

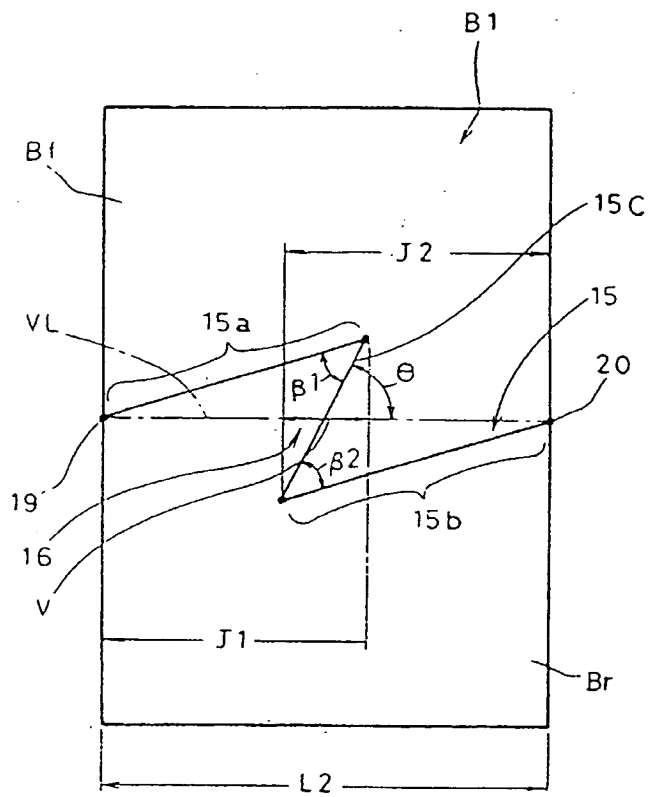

Fig. 5

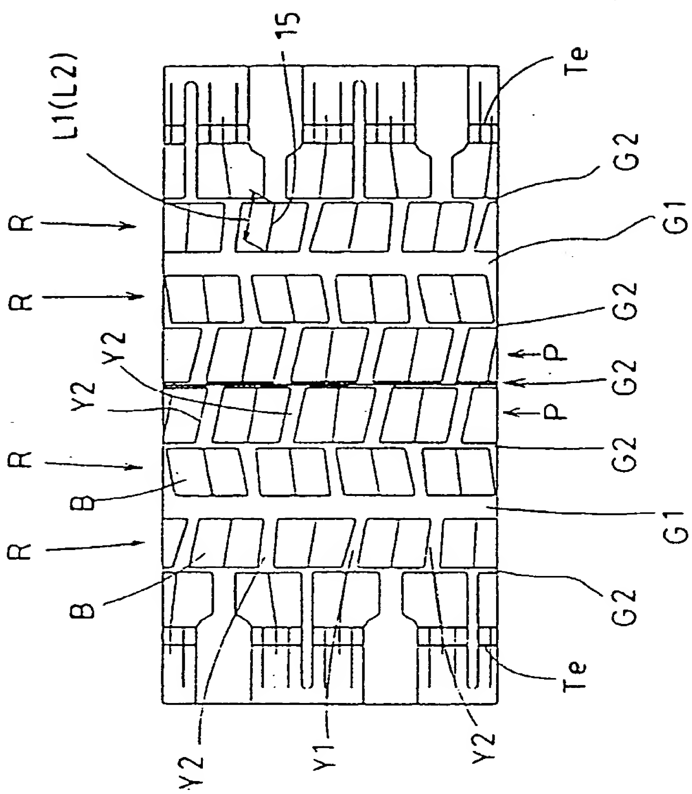

Fig. 6

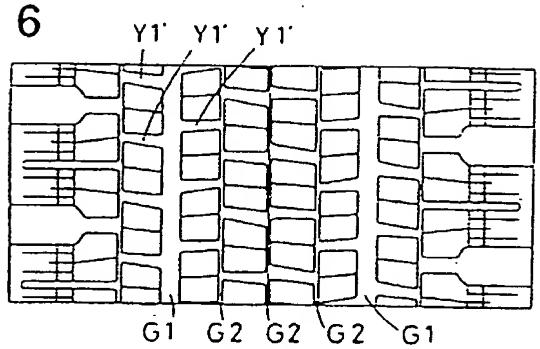

Fig. 7

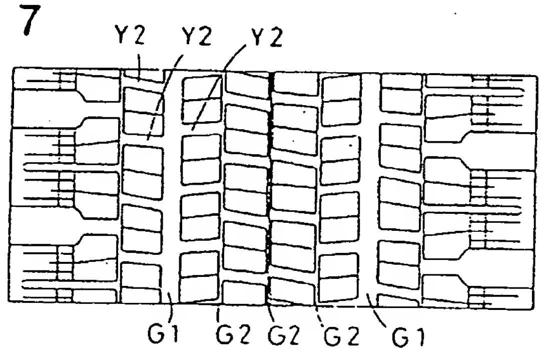

Fig. 8